MUNICIPAL WATER RATES[1]

By E. E. Bankson[2], D. E. Davis[2] and C. A. Finley[3]

The development of scientific rate making has been coincident with the advent of the Public Service Commission, wherein the majority of cases dealt with are the relatively small privately owned plants susceptible to considerations in operation which are often entirely submerged and of little value in the operation of large municipally owned plants. This paper is presented with the view of creating further interest in this much neglected field.

The operation of a municipally owned plant affords the opportunity for rate making on the basis of true equity and free from temptations to adopt policies of financial expediency appealing to privately owned plants. There are many elements in common to both plants creating influences in rate making which are often reflected in widely varying results, due to the radical differences in policy adopted by the directors of a private corporation in the one and the legislators of a municipality in the other case.

The operation of privately owned plants in many states is under the jurisdiction of the Public Service Commission, where a revenue is recognized sufficient to provide a fair return on the fair value of the property, in addition to operating expenses and an allowance for depreciation of plant. The reasonableness of rates imposed by a private water company would necessarily be measured by application of the rulings of the Public Service Commission.

The operation of municipally owned plants is generally not under the control of the Public Service Commission, which fact permits different principles to be applied in the two cases. The duty of the Commission is to protect the interests of both the consumers, as members of the community, and the water company, as a private concern; but the consumers may exercise their control of a municipally owned plant through the power of their vote.

[1] Presented before the Cleveland Convention, June 7, 1921. Discussion is invited and should be sent to the Editor.

[2] The J. N. Chester Engineers, Pittsburgh, Pa.

[3] Managing Engineer, Bureau of Water, City of Pittsburgh.

The opportunity for variations between municipal rates results from differences in the so-called ownership of a municipal plant. The latter depends on the proportion of the investment contributed by property through tax assessments as contrasted with excess earnings gathered from water revenue and invested in plants. The reader will here understand that the expression "so-called ownership" is used as a convenient term to indicate the source of money that built the plant. Unless this factor is recognized in the building of the rate schedule, some discrimination may result toward one or the other of the contributors to the plant cost, i.e., the property owner on the one side or the water consumer as such on the other side. The equity of rates imposed by a municipal plant would seem to depend, therefore, on this seat of so-called ownership.

A municipality may operate its water plant at a profit as a separate source of municipal revenue if it is disposed to do so and the law does not prevent. Such operation may favor the property owner who does not take water in proportion to the value of his property, such as owners of vacant property or of extremely valuable property requiring a small quantity of water. On the other hand, if the plant be operated at a loss with the deficiency repaired from the general tax levy, the water taker or consumer as such would then be favored at the expense of the tax-payer.

The thought often exists in the mind of the layman that substantial justice will be done if all revenue is derived from water sales, since the consumer and the property owner are substantially one and the same. That this is not strictly true is evident when we consider such extreme cases as the valuable vacant property or the large office building, which enjoys water service, fire protection, and increased property value out of all proportion to the relatively small charges for water used, on one hand, and the very large consumer of water, on the other, whose business is housed within a relatively inexpensive building or property.

The decision to operate a municipal plant at a profit, or at a loss, however, is to be determined in part by administrative policy, rather than as entirely a question of scientific rate making. If accurate cost analysis is to play any part in the problem of rate making, however, it must precede and remain separate from questions of administrative policy, except that the term "cost of service" may be subject to different interpretations according to the administrative policy obtaining. The results of cost analysis are to be used

for the purpose of moulding or indicating the correct administrative policy in this respect. The major purpose of this discussion being "Total Cost of Service," resulting in the "Rate Base" or "Total Annual Burden" and the equitable distribution of this burden among the various consumers of a municipally owned water plant, we intend that any mention of administrative policy in connection with cost be considered only as contributory discussion.

Cost of service. Cost of water service as deduced from the practice of Public Utility Commissions in their control of privately owned plants, is made up as follows: (a) Fair return on a fair plant value, (b) an allowance for plant depreciation, (c) cost of plant operation and maintenance, wherein the item for "fair return" incorporates any profit permitted for the utility. The three items indicated are based on used and useful plant value.

This discussion of absolute cost of service rendered by a municipal water plant will not incorporate an item of profit, and consequently the item of "fair return" for private plant will be replaced by an item which may be designated as "interest on capital invested." Where the so-called ownership of plant, bonded indebtedness, sinking fund, and interest rate paid may vary with each plant, it follows that the total cost of service will vary with each municipal plant, though the terms "depreciation and operation" carry the same meaning as indicated above. This "cost of service" as distributed to the consumers through the medium of the rates charged will be further dealt with under the heading "Distribution of the Burden."

Ownership of plant. There is no contention that the City does not own the plant, but there does appear to be a difference in equitable rates, dependent on the source of funds for plant purchase. The two sources are the general tax levy and the charges for water service, as illustrated in the following comparison.

The water works plant of the City of Toronto, Canada, appears to be bonded to more than its present value, and Akron, Ohio, only slightly less, as indicated in the tabulation of "Plant Statistics." This means, in a sense, that the bond holders own the plant and the cost of service must incorporate the total interest on the bonded debt. Unless, in addition, the water revenue provides also a sinking fund for retirement of bonds, the water takers as such will never hold any equity in plant account. If the operating revenue, in this case, should provide a sinking fund, in addition to interest and operating cost, the rates would ordinarily need to be as high or higher than those permitted for a private plant.

The water works plant of the city of Erie, for purposes of this discussion, may be considered free of debt. Since there are no interest or sinking fund charges to meet, one might easily and erroneously conclude that the water rates in Erie should be much less than in Toronto. Such is not necessarily the case, for the water rates in Erie provide the only source of revenue for plant extension and replacements. In other words, the water takers in Erie are paying for their plant as they go along, and for the past ten years this cost has been approximately equal to 6 per cent on the plant cost. This item therefore takes the place of interest and sinking fund for a bonded plant in the "cost of service" for Erie. If Erie should ever stop growing, however, and no further plant extensions should be necessary, this item would disappear from the "cost of service" and the water rates should decrease accordingly, whereupon the advantage of this position would be more apparent. From the above discussion, it is evident that the water takers have provided the funds for investment cost of the Erie plant and in the spirit of this discussion we might say that the water takers or consumers own the Erie plant.

The water revenue in many other cases is insufficient to carry the annual burden and any bonds retired would indicte a credit to the general tax levy, which should entitle the tax levy to the regular city interest rate on all plant investment actually made. In setting up the "cost of service," the general tax levy should receive a ledger credit for providing these funds, resulting in a corresponding charge to the water takers, which would appear in the "cost of service" distributed among the individual water accounts through the rates applied, with public service and fire protection carrying a proper portion of the cost.

We understand that the present policy in the city of Cleveland provides that the ownership of small distributing street mains and service lines to the curb is vested in the property owner. At any rate he foots the bill and carries that entire burden by direct assessment, as for sewers or for street paving. In the City of Erie, however, the total burden is carried by the Water Department, thereby creating a difference in the basis for equitable rates in the two cases. In the one case, the consumer has gone down in his pocket and paid outright for his service line and street main, or, if he is a renter, he meets that burden through his house rent, while in the other case the burden of said items appears in the water rates, corresponding to a

return on investment. This variation results from the different location or seat of plant ownership of the items in question.

The city of Pittsburgh offers a third comparison in this connection. There the property owner assumes the burden of the service line and the Water Department that of the service mains. A difference as to ownership of meters offers yet another comparison. The purpose of presenting the foregoing examples is to lend support to the statement that the rates charged for water in one city offer no evidence of equitable rates to be charged in another city or in a private plant. Each case must be analyzed separately and must stand on its own merits under the full conditions obtaining in each instance.

In support of the thought that each schedule of rates stands alone, we tabulate, on the following page, data from replies to questionnaires sent to several cities. This tabulation indicates, among other things, that the bonded debt and resulting fixed charges vary from 0 per cent to 100 per cent, that the plant value varies from \$19.75 to \$88.00 per capita and that the operating cost ranges from \$0.92 to \$3.22 per capita or from \$18.00 to \$95.00 per million gallons.

Another deduction from this table, which may be of interest to some, is that an average plant value is slightly less than \$40.00 per capita, while the average operating cost for 1919 was slightly less than \$40.00 per million gallons, although this figure would be reduced in normal times.

It is entirely possible that there may have been some discrepancies in interpretation of both questions and answers preliminary to the formation of this table, which would give erroneous results, but we have no evidence of error in the figures submitted. We use them here as illustrative of our position. The results should dispel any idea that water rates in different cities may be compared, for a comparison in total means nothing.

Service rendered. The functions of a water works plant are admittedly two-fold, that of furnishing a water supply for general consumption and for fire protection. Since this discussion is based on the principle that "the rates charged for any service should be in proportion to the cost of such service," it becomes necessary to make a careful analysis of all functions and duties assumed by the water department and of all service rendered.

Fire protection service is rendered to property or to property owners in proportion to the value of the property protected. Charges for such service, therefore, should be entered directly against the prop-

erty or against the general tax levy. General water service is rendered to persons or industries largely in proportion to the water delivery, with no necessary relation between value of property and quantity of water delivered. To make a proper accounting for all service rendered, the charge for water cannot properly cover fire protection, for there is no necessary relation between the two, and in fairness to all concerned, a charge for fire protection must appear separate in a complete schedule for equitable rates.

The provision of a water supply for fire protection service creates an increase in plant investment and in plant operation over and above the costs which would be sufficient for general water service. The exact cost of fire protection service has been somewhat in doubt within the limits of the two methods of computation used, that is, the excess method and the proportional method. After a careful analysis has been made of fire protection service rendered by any plant, a cost for this service, however, can with fairness be established and a charge indicated in that amount. In the case of the City of Pittsburgh the ratios chargeable to each service were obtained from available records of actual demands. The result was checked fairly well by the equation proposed by Metcalf, Kuichling and Hawley in the 1911 Proceedings of this Association.

General water service may first be separated into two groups as public service and private service. If the tax levy carries the burden of plant investment this may amount to more than the cost of the public service received by the city and by property in general. In such a case the ledger should show a credit to that extent, in this way offsetting the charge for public service. General water service is again divided according to flat rate service and metered or measured service.

Flat rate service. The flat rate method of charging for water service, a heritage to us from pioneers in the water works field, carries the approval of the wasteful user, because it permits his extravagance at public expense. It does not seem to disappear rapidly through a process of the survival of the fittest. It would seem, therefore, to devolve wholly on the water works men to gradually make obsolete the flat rate system. Flat rate charges or assessments are admittedly inequitable and conducive to wasteful habits. But being yet with us, they should always appear in excess of meter rate charges, for the same amount of service, with the hope that such a practice will create converts to the metered or measured service method, although experience shows the latter to be not always the case.

The average domestic flat rate in the city of Pittsburgh is 55 per cent in excess of the meter rate for similar service, but every flat rate consumer has the option of transferring to measured service if he so desires. Even with this high flat rate there remains under flat rate service approximately two-thirds of the total number of consumers with no apparent desire to avail themselves of the economy offered. In fact most of the metering accomplished has been of a compulsory nature.

The Pittsburgh plant has a capacity in excess of fully metered requirements. It is interesting to discover through cost analysis that no economy may be effected by metering the entire city at once; or at any rate in excess of that necessary to reclaim plant capacity from wasteful service to useful service, or additional demands, as conditions may require. In the case of Erie, however, the plant capacity has been reached under the present flat rate policy, and it is clearly evident, in the interests of economy, that a policy of metering domestic consumers should be adopted.

Metering may reduce domestic consumption by more than half, which has the same effect as increasing plant capacity. It is far cheaper to meter than to build additional plants. It would be poor economy (in fact wasteful) to create additional plant capacity for the purpose of supplying flat rate consumers, instead of placing them under measured service. Aside from discussion along lines similar to the above, we cannot see that flat rates have any place in scientific rate making, for flat rates are subject to the laws of neither science nor equity.

Measured service. In the case of the city of Pittsburgh, the computed demand under fully metered conditions would show a reduction of 40 per cent from the present pumpage. Such a reduction represents no curtailment of useful service, but it represents rather the reducible leakage and careless running of water to waste, which simply flows down the sewer and does service to no one.

There appears a common error among water works men and engineers of overestimating the amount of water which will be used when a city is fully metered, with the result that a financial deficit appears as metering progresses. This tendency to overestimate is a logical result of a habit formed in designing plant capacity for maximum conditions. Such a designer carries this habit over into the field of rate making, where he discovers, too late, that his measuring stick was too large and the revenue is not realized as computed.

We have also observed a tendency, on the part of the inexperienced, to use the present pumpage of a flat rate system, as the starting point to forecast future revenue under fully measured service. They apparently forget that there is no reliable relation between the two and that revenue is indicated by the dial on the consumer meter rather than by the pump counter.

Such errors are entirely unnecessary today with the progress which has been made by those who are successful in this department of water works affairs. The revenue under fully metered conditions may be fairly and safely computed by an intelligent analysis of complete and detailed consumer data in each case. To make this clearer we tabulate below the results of two cases coming within our experience.

CONSUMER CLASS	AVERAGE GALLONS TAKEN PER YEAR	
	St. Mary's, Pa.	Pittsburgh, Pa.
1. Single spigot consumers	7,500	32,000
2. Single spigot plus toilet	10,300	42,000
3. Set of complete fixtures within the building	27,800	50,000
4. Set of complete fixtures including sprinkling	45,200	64,000

The high figures for Pittsburgh might be explained by the fact that the excessive smoke and dust demand more washing on the part of the public. In addition, the pressure at the spigot is rather

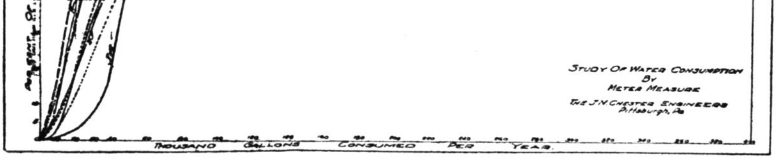

Fig. 1. Curves Showing Percentage of Metered Consumers Taking Less Than Indicated Amounts of Water

high, an average of 79 lbs., while the maximum at different points is in excess of 100 lbs. The divergence of the Pittsburgh results, in excess of the normal, is clearly shown by means of consumer curves and tabulation as attached herewith. The curve for Pittsburgh appears to the right of all other curves and is designated as curve "J."

Water consumption, as shown by actual meter readings (forecast for Erie)

CITY OR BOROUGH	GALLONS PER YEAR PER METER	GALLONS PER DAY PER METRR	GALLONS PER CAPITA PER DAY—5 PERSONS PER METER
1. Popular consumption			
Knoxville, Tenn.	25,000	68.5	13.7
Jefferson City, Mo.	27,375	75.0	15.0
St. Marys, Pa.	23,000	63.0	12.6
Scottdale, Pa.	17,000	47.0	9.4
Ellwood City, Pa.	18,000	50	10.0
Milwaukee, Wis.	25,000	68.5	13.7
Forecast for Erie	31,000	85	17.0
Pittsburgh, Pa.	42,000	115	23
2. Consumption at 50 per cent point on consumer curve			
Average of ten American cities (including Cleveland)	42,000	110	22.0
Knoxville, Tenn.	27,000	74	14.8
Jefferson City, Mo.	26,000	72	14.4
St. Marys, Pa.	25,000	72	14.4
Scottdale, Pa.	22,000	61	12.2
Ellwood City, Pa.	27,000	74	14.8
Madison, Wis.	36,000	99	19.8
Milwaukee, Wis.	42,000	110	22.0
Forecast for Erie,	42,000	110	22.0
Pittsburgh, Pa.	52,500	144	28.8

The relation between fixtures and annual consumption was developed in the Pittsburgh case as shown by the following curve.

Distribution of the burden. Meter rate schedules are generally one of three types: (1) Straight price to all per 1000 gallons, (2) minimum charge type, (3) service charge type. Nos. 2 and 3 are on the basis of either a straight price or a sliding scale in addition to certain fixed charges. It is generally conceded that it costs more per 1000 gallons to serve a small than a large consumer. If this fact be admitted, we thereby eliminate the straight-price or flat-price-to-all idea.

A minimum charge type sliding rate schedule can be constructed which would closely approach the costs of rendering the service, but the Public Service Commission of New York has ruled against the minimum charge type in a gas case in the following words which apply equally well to water:

The minimum gas rate is inequitable. A sample case cited is the best proof. Mr. A. and Mr. B. are in the minimum class, which is placed, say, at $1.00. Mr. A. used 90 cents worth of gas a month; he pays $1.00. Mr. B. uses 20 cents worth of gas a month; he also pays $1.00. If the interest on the service investment to that residence or office is 50 cents, the company sustains a loss from Mr. A. of 40 cents that must be made up by some other consumer, while it has made a profit of 30 cents off Mr. B.

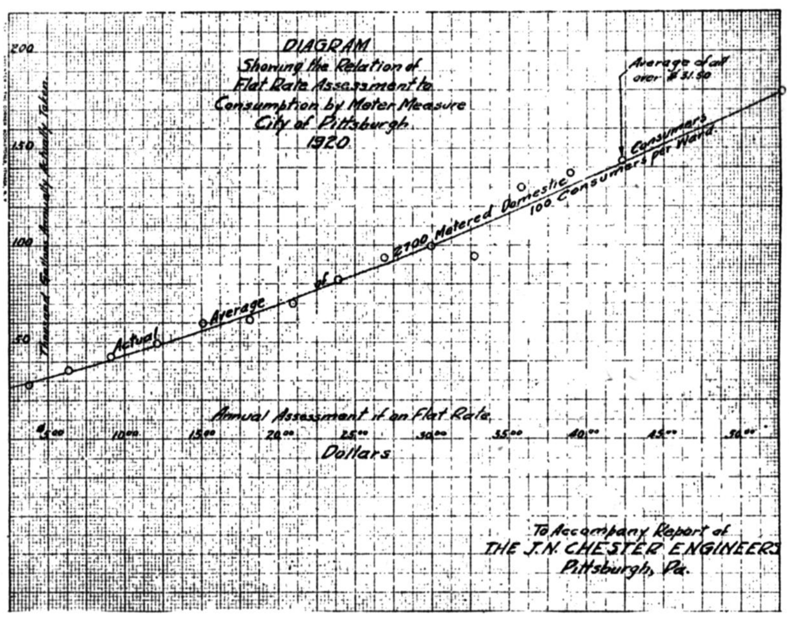

FIG. 2. RELATION OF FLAT RATE ASSESSMENT TO CONSUMPTION BY METER MEASURE

The service charge is recognized by the New York Commission in these words, "A service charge . . . . is a legal and just charge if properly adjusted as to amount." The association of Boroughs in Pennsylvania, on advice of their counsel, has recently withdrawn a proposed bill intending to make the service charge illegal in Pennsylvania. These and many other incidents seem to indicate to the writers the increasing recognition of the service charge.

Service charge limitations. Advocates of the service charge have included portions of the total annual burden under this charge, ranging all the way from "simple consumer charge" to "entire fixed charge and overhead expense."

The writers maintain that a proper service charge is usually in excess of a simple consumer charge, but much less than the total fixed charges and overhead expenses. They have developed principles on which the service charge may fairly be computed, as indicated in two examples appearing at the end of this discussion. The service charge is based on the assumption that a company stands ready, under certain expense, to do a service or sell a commodity for which no purchaser may materialize. Insofar as it is compelled to do so or is reasonably in danger of having to do so, the company is undoubtly entitled to financial remuneration and to have its financial position insured.

It is not a fixed condition that may be applied empirically to all plants, but exists between two limitations which may be designated as the maximum service charge, where the plant stands ready to deliver and no water is taken, and the minimum service charge where the size, diversity, and variety of consumers maintain practically a constant demand on the plant.

It is assumed that in order to warrant any service charge, it must be shown that the conditions on which it is based actually exist. It must be a real condition and not based on any theory of what might or could happen. It must be based on common sense and actual facts developed from the operating conditions of the plant in question.

The full or maximum service charge may be outlined as that of a plant fully manned, with reservoirs full and pipe lines under pressure running at a rate just sufficient to offset leakage losses, but with no one taking water. The minimum service charge may be conceived as in a plant whose customers maintain a constant cycle of demands on the plant and where there is no loss due to standing ready to serve.

A typical example of the maximum service charge condition would be a plant having one customer taking the entire output, but taking it at such irregular times and in such uncertain quantities that the plant was compelled to keep its entire equipment ready for operation at a moment's notice. The cost to this plant, even when no water whatever was taken, might easily be 90 per cent or more of its full operating cost. The plant in this case is rendering what may be typically designated as a service, as distinguished from the sale of a

commodity. It is, therefore, entitled to remuneration for this service. The service in this case financially predominates over the sale of the commodity.

A representative type of a minimum service charge may be taken as that of a large city plant having, say 100,000 customers, whose varied demands on the plant impose on it practically a fixed cycle of conditions hourly, daily, weekly and seasonally. Such a plant is usually so designed that it is practically at no actual expense on account of standing ready to serve a commodity for which there is no purchaser. Its function is the sale of a commodity, as distinguished from the readiness to sell. Practically speaking, the maximum loss directly imposed by failure of a purchaser is the loss incident to the service line, the meter and the reading and billing. With these determined, they may be designated as a minimum service charge, as distinct on the other extreme from a maximum service charge. The maximum service charge may be considered in its application to a certain large city plant where the average rate for water is about 15 cents per thousand gallons and serves about 100,000 customers. If the theory of the service charge be carried to its logical sequence and it is assumed that all customers withdraw their patronage, the expense of this plant would still be over 90 per cent of its active operating cost. If this 90 per cent were provided for in a service charge, the price of the water would be about 1½ cents per thousand gallons, with the result that the plant would be on a flat rate basis and meters would be of no practical value. As a matter of fact, this plant (aside from fire protection) is not primarily in the business of furnishing a service but of selling a commodity. It suffers practically no financial risk or possible embarrassment from standing ready to serve. It does lose the interest and maintenance on the meter in addition to the billing charges, when the customer fails to buy and is entitled to collect for this in the event of the customer's failure. The two extremes in the type of plant have been taken to show the wide possible range of a service charge designed to meet the financial risk imposed on a plant in standing ready to serve. At one extreme, the service cost takes precedence over the commodity charge and amounts to practically the whole bill. In the other instance, the commodity charge takes precedence and nearly absorbs the service charge. The range of possibilities between these two extremes is infinite.

In the case of the Consolidated Ice Company vs. the City of Pittsburgh, it was necessary, in the interests of the city, to combat a theory which developed a high service charge and a low commodity charge, and we quote from the testimony of Mr. Finley in that case as follows:

To maintain this condition in the Pittsburgh Plant, even if no water were sold, means the pumping of about fifteen billion gallons per year to keep the plant full. The cost of supplying these fifteen billion gallons, instead of the forty-five billions now handled, would be a large percentage of the present cost, substantially the entire cost except as follows: the saving due to not pumping the thirty billion gallons which the consumers now use would be about $350,000.00 (out of a total annual burden of about $2,650,000) and the ready to serve charge would be the total cost of production less this $350,000.00. If now the suggested method of allocating this charge according to the suggested basis in fixed quantities against the consumers is adopted and the $350,000.00 is allocated amongst the consumers according to the amount of water used, then to all practical intents and purposes, the city is back again on a flat rate assessment basis, except for the fact that consumer, in addition to the fixed amount laid up against him, would pay something over one cent a thousand gallons for the water consumed. This means that the entire economic value of metering would disappear. There would be no check on the waste of water, no personal interest on the consumers part to eliminate waste and the unnecessary outlay of capital in order to handle this waste would then obtain. . . . . If the art of supplying water to large communities is to make any economic progress, and there is no question as to the desirability of this end, it must not be defeated by any false rate hypothesis which takes but little account of the amount of water used and virtually harks back to the flat rate theory based on what might, or could, or should be demanded of the plant. The water meter is the instrument by which great advance in the economy of the art is to be effected. It introduces the element of self-interest in the relation of the consumer to the producer and produces a result which no amount of inspection, argument or propaganda can accomplish. It shows on its dial just what has happened to the plant regardless of the value of any orifice and what it might or might not have demanded. It reveals the big consumer and the little consumer in their true relations and it is not surprising that many rate schemes have been developed, the purpose of which has been to defeat the objects of metering and to escape the responsibility of paying in accordance with the meter readings. Any such rate scheme which submerges the retarding influence of the meter, on waste water, smothers the greatest opportunity for economic advancement available at the present day in the art of supplying water.

A proposed method for distribution of the burden. The usual assumptions underlying the construction of rates are that the total revenue to be derived may be divided into three broad classifications, which roughly correspond to the costs. These are the

consumer, demand and output costs. The consumer costs are taken as those costs (actually derived from a study of the company's books) which cover the reading of meters and billing of charges, book-keeping costs, stationery and those costs which have no reference to the quantity of water used by the consumer, but which are practically the same for each consumer regardless of size.

The demand charge in bulk is assumed to cover such costs as have to do with the possible peak load demands on the plant, such as fires or sudden large momentary uses of water. Since the investment in nearly all elements of the plant including the distribution system is necessarily much greater in order to care for peak loads, than would be true for uniform, non-fluctuating loads, it has usually been assumed that all charges connected with investment, such as interest charges, are included in this category. A portion of the time of certain executive officers is also thought of as being properly chargeable to this account. Having determined the bulk figure, the distribution to the individual consumers is usually effected by finding the total "capacity" of the individual consumers, on the assumption that the area of the service lines or meters supplying the property is a fair measure of the demand which the consumer may make upon the system. When this individual capacity charge is found, it is usually combined with the "consumer charge" in order to form a "service charge" usually based on the size of meter. In practice, the strict application of the theory is usually *considerably* modified by the introduction of a more or less arbitrary diversity factor.

The "output charge" covers such costs as fuel, labor of station employees, chemicals, etc., and varies strictly with the quantity of water pumped. The larger the pumpage the lower this unit cost.

There is little dispute as to the fact that these three general classes of costs do apply in a water works plant. The only divergence of opinion would arise as to their derivation and constitution, and as to their equitable distribution in a rate schedule when once determined. It is in the desire to stimulate further discussion of this problem and in the hope that ultimately a more-or-less standardized method of procedure may be derived and agreed upon that this discussion has been undertaken.

When the foregoing premises are examined, little objection can be suggested to the methods employed in arriving at or in distributing the "consumer" or the "output charge." When the "demand

charge" is similarly examined, however, some of the present methods appear open to question on both counts. It may as well be conceded at this point that no hard and fast rule may be employed in the making of the final rate. Considerations other than those dictated by pure theory must often times be consulted in arriving at the final determination. The making of a rate involves judgments of a judicial character. Questions of expediency often modify the rate derived from a disinterested study of the conditions at the plant. However, in the building of the rate it will probably be conceded that reasonable assumptions corresponding as closely as possible to the known conditions of the plant should be employed. There are several premises in the methods used in deriving and distributing the "demand charge" which appear to the writers not to correspond with the ordinary observable conditions of plant operation.

What are these conditions which are common to all plants and are a matter of every day acceptance in their operation? As to the physical aspects they are essentially these: The plant at a given time furnishes an average daily quantity of water which remains fairly constant from year to year. There is, however, a very wide variation in the consumption during any one day, the minimum being at night and the maximum usually about 10:00 a.m. There is also a seasonal variation; the summer demands and the winter peaks usually exceeding considerably the average consumption. Finally, each plant recognizes the possibility of a set of circumstances which may put a very heavy demand on the plant for a brief period. In addition to these considerations there is always the opportunity that the plant may be called upon to supply water for a heavy conflagration.

On the back-of-the-counter side of the water works office there is another factor which can be counted upon with the same degree of certainty as the average annual consumption. This is the assurance, built up during a long association with the conditions of water works practice, that the consumers can be depended upon to continue their use of water, and, consequently, that the money will come over the counter in a fairly uniform stream from year to year, the growth of the population being taken into consideration.

These are well understood characteristics which are common to the personalities of all plants. In the casting of many rates these conditions have not had an opportunity to be reflected, but have been replaced by theoretical assumptions which do not correspond with the facts.

The justification for the service charge, as advanced by its advocates, starts with the idea that the utility must meet certain fixed and administrative charges whether water is delivered to the consumers or not. It is implied, therefore, that there should be a certain stated charge made against each consumer over and above the charge for water and which will apply whether any water is used or not. This idea seems to be entirely reasonable, when properly applied, because there are certain investment charges against his specific installation for which the utility should receive adequate return in the rates secured from him, and which conceivably a charge against consumption alone would not always cover. The strict application of the usual theory would build up, however, such a large service charge as to make this portion of the consumer's bill the largest item, in the case of the majority of consumers. This would be true, because in the ordinary case most of the fixed charges are thrown into this item. After the fire protection charge to the City (which is chargeable against this item) is taken out, the amount still levied upon the consumer is high.

The fallacy in this premise, as it appears to the writers, lies in the assumption that the whole of the fixed charges should be placed into the demand classification. This idea neglects the obvious fact that the plant is constructed not only for a large demand but primarily for day to day service to consumers. Furthermore the habits of the consumers are fairly well established and quite constant. The assumption that they as a body will suddenly cease to use water is strictly opposed to the facts. The revenue, however the rate is formed, has the habit of coming into the office with due regularity.

All that the utility can reasonably expect is that a sufficient charge in the form of a service rate be assessed against the consumer as will cover the legitimate costs of investment assessable against him, so that if for some reason, such as absence on vacations, his consumption becomes abnormally low, there will still be enough revenue derived to carry his account.

To point out other apparent defects in the present theory and to suggest possible remedies, it will be necessary to enter into a discussion of some of the details of rate making. Admitting that the element of judgment must enter into the determination of the form of the rate finally adopted, yet it certainly will be desirable to fix limits within which this function may operate. In order to fix the lower limit it will be convenient to inquire as to what would be the minimum investment required for supplying the water to consumers.

It is obvious that the absolute minimum investment would be the one in that plant which would be required to work regularly, uniformly and continuously for 24 hours per day, 365 days per year, delivering the total required quantity, but uniformly and not as at present—as demanded. Such a condition might be conceived if each consumer were thought of as having a storage tank which would equalize all of his fluctuations and into which the utility would deliver water at a uniform rate. Obviously the plant investment for this arrangement would be much less than for the plants actually erected, and this condition would extend from the pumps to the filters, buildings and distribution system and would include some reduction even in the size of the consumer's meter and soemtimes his service line. This would be the absolute minimum for a plant which would render average day to day service. It is our belief that at least this much of the investment (and probably more) will be required for ordinary service. The utility could not get along with less.

If this be granted and if it is also conceded that the principal reason for the existence of the plant at all is the serving of the daily needs of the consumer, *it would seem that this much at least* of the fixed charges on the plant investment *is chargeable directly against the consumption,* since in such a plant the summation of all consumptions (or total annual consumption), when divided into the total fixed charges, would represent the price per unit which, when applied to the consumption of each consumer, would fix the proportion of the whole cost which he should bear. This charge then is strictly proportional to the actual average consumption. Contrary to the usual practice then, it would seem that *this cost should be made a part oj the output charge,* which is made on the basis of actual consumption of water.

A good example of a minimum plant, as regards the water supply element in plant investment, would be a gravity supply with a reservoir large enough to supply all deficiencies in stream flow. Any hourly or day-to-day fluctuations in load would affect such a large reservoir not at all. The same reservoir would be required whether the consumptions were uniform or fluctuating and the fixed charges against a storage reservoir would therefore appear entirely in the output charge.

Having now allocated to output charge certain elements of cost, which in the past have been considered as applicable to demand and have been made up into the service charge, there remain certain

costs which admittedly should be included under the demand heading. A suggested method of dealing with these costs will now be discussed.

The method proposed is that of splitting up the plant investment into various categories representing like service, such as pumping station and accessories, filtration plant, reservoirs, carrying mains, gridiron distribution system and services and meters. Having accomplished this, the next step involves a study of the probable relation between the normal use and the maximum demand on each element. This may best be illustrated by example. An examination of the pumpage record of the plant is made and the average daily pumpage determined, as is also the maximum hour's pumpage at any time during the year. If a record of pumpage during a heavy fire can be found this is also recorded, or else the maximum pumpage possibilities of the plant used. Assume that the results are as follows:

	Gallons
Average daily pumpage rate	1,000,000
Maximum hourly pumpage rate	2,000,000
Fire	2,500,000

then for convenience the investment costs woud be broken up as follows: 1/2.5 to output charge, (2-1)/2.5 to demand charge and (2.5–2)/2.5 to fire protection service. A little consideration of the activities of the average water works plant will indicate that there may be and usually is a wide variation between the demands of the various elements of the plant. These will also vary with the size of the plant, the larger the plant the smaller the variation. The greatest fluctuations will occur the nearer the consumer is approached. The diversity factor or ironing out effect becomes more pronounced the nearer to the source of supply. It is practically impossible and really unnecessary to determine the actual demand of each consumer, but it will be sufficiently accurate to consider the different classes of consumers based on the sizes of their meters. As a measure of the demands of various consumers we have employed the study of this subject as made by the committee on meter rates for the New England Water Works Association which appears in the December issue of the 1916 JOURNAL. The entire fixed charges on all meters is first allocated to the various groups of meters and the amount to output and to demand fixed by reference to the relation between average use and maximum demand. It is assumed for convenience that the investment in an "average" meter and the

actual meter in use (which is large enough to supply the maximum demand) will be proportional to the demands in each case. The cost of repairs to meters probably bears a close relationship to the investment in meters and this cost is distributed between the classes of meters in proportion to the investment.

A fair basis for distributing the costs of the gridiron system is next sought. It is believed that the fairest basis is that found by assigning the costs directly on the basis of the total number of consumers. A more or less arbitrary distinction must be made between carrying mains and gridiron system, the former representing in this discussion the large arteries emanating from the plant which carry water out to distant districts and to which the smaller mains connect to distribute the water to the consumers themselves.

The size of the gridiron lines is largely dictated by friction loss considerations, it being necessary for the lines to be large enough to furnish fire streams without undue pressure loss. The mileage in these mains has little reference to actual or relative consumptions, but they are made necessary by the fact that the population lives in homes that are scattered over a wide area, and by whose properties water lines must be laid in order to render service. The investment in these lines varies more nearly with the population than with consumption, as such, and it seems fair then to consider that the investment in gridiron system is the same for each consumer. That it probably does not vary with consumption directly might be seen if it were assumed that in a given plant one large industrial consumer, located near the plant, used as much water as all of the remaining population, yet this fact would make little difference in the mileage of mains; they would be required in any event in order to supply the remaining consumers. Any increase in consumers involving building up of new territory would require proportionately greater mileage.

In the distribution of this burden the fire protection charge would ordinarily take the largest share of the cost, and the distribution of the remaining costs between "output" and "demand" would be made with reference to actually observed demands on various parts of the system where records were available. The further distribution between individual classes of consumers would have to be a question of judgment, but the limits would probably be fairly well defined. The tabulation at the end of this paper, in which a complete example is worked out, will explain the method in greater detail. The ratios for each division having been obtained by obser-

vation of actual conditions for this plant, these changes are distributed among the different classes of consumers by methods similar to that for meters.

The consumptions of the various classes of consumers are probably the best basis upon which to distribute the fixed charges on carrying mains, after a figure has been arrived at for charge to fire protection. In a majority of cities the consumption, both large and small, may be distributed at various, widely scattered locations throughout the city. The carrying mains must be large enough to supply these maximum collective demands or consumptions.

Since the quantity of water to be delivered at various controlling areas, not necessarily influenced by distance alone, is the basis for the design of the carrying mains, it would appear that the money that went into its construction would bear a closer relation to the consumption than to any other feature. The ratio between the average daily use and the maximum demand becomes less as the source of supply is approached, and the ratios in the carrying mains are less than in the gridiron.

The consumption basis for the distribution of costs has been used in each of the remaining classes of service with the exception of "consumer costs," where such items as book-keeping, billing, reading meters, etc., have been distributed directly in proportion to the total number of consumers, and the result carried into the sum which later forms the "service charge."

Having assembled the "demand and "output" charges for all consumers on the same sized meters the average output charge is found by dividing the total output costs by the total annual consumption for that class, and the "service charge" by dividing the corresponding sum by the total number of consumers in that class. It then becomes a relatively simple matter to work out an output curve which will substantially fit the average output figures shown in the computed results.

It is intended that such an analysis as here proposed should serve as a cost study preliminary to the administrative decision or the adjudication resulting in the final rate schedule. A concrete illustration of the method discussed will be found in the following tabulations: In the first, the conditions are similar to those which are to be found in a plant serving a population of approximately 50,000 people, while in the second a population of approximately 3500 is considered.

Water plant statistics for 1919–1920

CITY	POPULATION	PLANT VALUE	BONDS OUTSTANDING	PLANT VALUATION PER CAPITA	OPERATING COSTS	OPERATING COSTS PER CAPITA	NUMBER CONSUMERS	OPERATING COST PER CONSUMER	MILLION GALLONS DAILY	OPERATING COST PER MILLION GALLONS
Cleveland	990,000	$28,000,000	12,000,000	$28.39	$953,936	$0.97	108,702	$8.75	127	$20.50
Toledo	260,000	12,500,000	1,915,000	48.00	382,335	1.47	45,500	8.40	28	37.30
Buffalo	510,000	19,198,490	12,847,492	37.60	890,948	1.74	76,258	11.70	136	18.00
Akron	160,000	10,000,000	9,000,000	62.50	267,000	1.67	32,000	8.35	20	36.50
Milwaukee	500,000	10,000,000	195,000	20.00	458,973	.92	66,422	6.92	61.9	20.40
St. Paul	250,000	7,443,707	2,407,000	29.75	247,722	.99	46,000	5.40	17.6	38.60
Youngstown	132,000	2,610,887	763,200	19.75	276,294	2.09	21,169	13.00	12	63.00
Toronto	499,276	16,000,000	16,209,316	32.00	1,150,599	2.30	104,766	11.00	75	42.00
Syracuse	171,000	15,000,000	4,105,000	88.00	249,395	1.45	25,450	10.00	27.5	25.00
Detroit	1,108,735	23,583,428	2,855,114	21.20	1,159,333	1.05	164,779	7.40	152	21.00
Sandusky	30,000				60,615	2.00	5,600	10.80	4	41.50
Indianapolis	267,000	10,000,000	*Private*	37.50			46,080		29	
Albany	112,568	3,099,000	1,520,850	27.50	360,100	3.22	20,674	17.40	20	49.30
Rochester	295,850	13,800,000	10,445,000	46.70	867,000	2.92	49,484	17.50	25	95.00
Canton	90,000	3,000,000	1,500,000	33.30			22,000		13	
Pittsburgh	547,000	32,000,000	10,698,392	58.50	1,422,762	2.60	91,617	15.50	118.4	32.83
Duluth	98,000	3,650,776	2,424,000	37.20	98,587	1.20	13,401	7.35	9	37.20
Harrisburg	76,917								9.1	
Totals	6,098,348	209,886,288	88,885,364		8,845,599		939,902		884.5	
Average (to here)				39.24		1.88		10.10		38.07
Erie	110,000	3,755,000		34.10	263,589	2.30	19,000	13.35	20.4	34.80
Minneapolis	300,000	11,000,000	1,750,000	33.30			61,000		27.5	
Williamsport	45,000	1,600,000	*Private*	35.50	77,141	1.71	11,000	7.00	8.5	24.86

Hypothetical Water Company, 50,000 population, apportionment of charges

		METER SIZES								TOTAL
		5/8 inch	3/4 inch	1 inch	1¼ and 1½ inch	2 inches	3 inches	4 inches	6 inches	
Number of consumers		7,750	840	379	69	68	27	17	12	9,162
Number of meters		7,817	846	383	74	75	32	20	14	9,261
Annual consumption—Mil. Gals.		414	114	125	54	118	208	248	348	1,629
Average consumption per meter—gallons		53,000	135,000	327,000	730,000	1,575,000	6,500,000	12,400,000	24,900,000	163,000
Fixed charge on meters	$13,417	$10,500	$154	$910	$217	$343	$287	$362	$64	$13,417
Ratios: Output 38, demand 134, Fire 0		116/705	580/1200	1700/2050	11/35	55/76	111/139	20/40	9/13	
—Distribution to output		$1,728	$75	$755	$161	$249	$207	180	445	$3,800
x Distribution to demand		8,772	79	155	56	94	80	182	199	9,617
xRepairs to meters—demand	$16,000	$12,525	$183	$1,085	$259	$408	$342	$431	$767	$16,000
Fixed charge on gridiron	$32,165									
Output and demand		$13,070	$1,414	$640	$116	$115	$46	$29	$20	$15,450
—Output		6,870	832	426	78	77	30	20	14	8,347
xDemand		6,200	582	214	38	38	16	9	6	7,103
oFire										1,6715
Fixed—reservoirs and supply lines	$50,590									
Output and demand		$8,990	$2,470	$2,710	$1,175	$2,560	$4,510	$5,380	$7,545	$35,340
—Output		4,495	$,370	1,690	840	1,830	3,220	3,850	5,380	22,675
xDemand		4,495	1,100	1,020	335	730	1,290	1,530	2,165	12,665
oFire										15,250
Fixed—pumping and filters	$57,130									
Output and demand		$13,065	$3,600	$3,950	$1,705	$3,725	$6,570	$7,830	$10,972	$51,417
—Output		9,320	2,400	2,820	1,310	3,100	5,480	6,530	9,140	40,100
xDemand		3,745	1,200	1,130	395	625	1,090	1,300	1,832	11,317
oFire										5,713

xBilling, collecting, etc.	$14,920	$12,590	$1,365	$617	$120	$121	$52	$32	$23	$14,920
—Operating expense	$116,400	$29,550	$8,150	$8,930	$3,860	$8,430	$14,880	$17,720	$24,880	$116,400
Totals:—										
oFire	$37,678									
xService	$71,622	$48,327	$4,509	$4,221	$1,203	$2,016	$2,870	$3,484	$4,992	$71,622
—Output	$191,322	51,963	12,827	14,621	6,249	13,686	23,817	28,300	39,859	191,322
	$300,622	$100,290	$17,336	$18,842	$7,452	$15,702	$26,687	$31,784	$44,851	$262,944
Average price per m. gals.		24.2c	15.2c	15.1c	13.8c	13.3c	12.8c	12.8c	12.8c	16.1c
Service		$6.18	$5.33	$11.00	$16.30	$26.90	$90.00	$174.00	$356	$7.73
Output		0.126	0.113	.117	0.116	0.116	9.115	0.114	0.114	0.118
Final rate adopted:										
Service		$6.00	$8.00	$10.00	$13.00	$20.00	$50.00	$100.00	$200.00	$7.17
Straight output charge of		0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

Small Water Company, 3,500 population, apportionment of charges

		METER SIZES						TOTAL
		5/8 inch	3/4 inch	1 inch	1 1/4 inch and 1 1/2 inch	2 inches	4 inches	
Number of consumers and meters		626	4	9	3	2	1	645
Annual consumption—gallons		14,553,600	508,700	7,194,400	1,957,600	5,887,300	6,871,600	36,973,200
Average consumption per meter—gallons		23,250	127,200	800,000	652,500	2,943,600	6,871,600	57,300
Fixed charge on meters, etc.	$1,829	$1,711	$17	$36	$23	$17	$25	$1,829
Ratios—Output 19, Demand 100, Fire 0.		116/705	580/1200	1700/2050	11/35	55/76	20/40	19/100
—Distribution to output		$282	$8	$30	$7	$12	$13	$352
x Distribution to demand		1,429	9	6	16	5	12	1,477
xRepairs to meters, etc. (demand)	$328	$307	$3	$6	$4	$3	$5	$328
Fixed charge on gridiron	$5,363							
Output and demand		2,705	$17	$40	$13	$9	$4	$2,788
—Output		1,420	10	27	8	6	2	1,473
xDemand		1,285	7	13	5	3	2	1,315
oFire								2,575
Fixed—on standpipe, force and carrying	$3,850							
Output and demand		$1,062	$37	$523	$143	$428	$502	$2,695
—Output		483	19	291	89	285	358	1,525
xDemand		579	18	232	54	143	144	1,170
oFire								1,155
Fixed—on pumping plant and filters	$8,839							$6,630
Output and demand		$2,608	$92	$1,290	$351	$1,057	$1,232	$6,630
—Output		1,630	58	862	234	755	880	4,419
xDemand		978	34	428	117	302	352	2,211
oFire								2,210

xBilling, collecting, etc.	$2,047	$1,986	$13	$29	$10	$6	$3	$2,047
xAdministration, etc.	3,000	1,763	35	399	112	319	372	3,000
—Operating Expense	$9,399	$3,905	$137	$1,935	$527	$1,585	$1,850	$9,939
oFire	$5,940							$5,940
xDemand service	11,548	88,327	$119	$1,113	$318	$781	$890	11,548
—Output	17,708	7,720	232	3,145	865	2,643	3,103	17,708
	$35,196	16,047	$351	$4,258	$1,183	$3,424	$3,993	$35,196
Average cost per M. gallons		$1.10	$.69	$.59	$.60	$.58	$.58	$.95
Service charge		$13.30	$29.80	$123.80	$106.90	$390.00	$890.00	$17.90
Output		0.53	0.46	0.44	0.44	0.45	0.45	0.48
Final rate = 4000 per quarter at 55 cents								
All over at 45 cents plus service charge of		$15.00	$35.00	$125.00	$200.00	$360.00	$600.00	